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FINAL

Remedial Action Plan for Full-Scale Bioventing Site FSA-1

Air Force Plant 4
Fort Worth, Texas

Prepared For

Air Force Center for Environmental Excellence
Technology Transfer Division
Brooks Air Force Base
San Antonio, Texas

ASC/EMR
Wright-Patterson Air Force Base
Dayton, Ohio

and

Lockheed Martin
Fort Worth, Texas

February 1996

PARSONS
ENGINEERING SCIENCE, INC.

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AQ M01-03-0485

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FINAL
REMEDIAL ACTION PLAN FOR FULL-SCALE BIOVENTING
SITE FSA-1
AIR FORCE PLANT 4
FORT WORTH, TEXAS

FEBRUARY 1996

Prepared for:

Air Force Center for Environmental Excellence
Brooks AFB, Texas

and

Lockheed Martin Company
Environmental Resources Management
Fort Worth, Texas

Prepared by:

Parsons Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado 80290

022/726876/159.WW6

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ACRYONYMS AND ABBREVIATIONS

AFCEE	Air Force Center for Environmental Excellence
AFB	Air Force Base
AFP4	Air Force Plant 4
bgs	Below ground surface
BRA	Baseline risk assessment
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CO_2	Carbon dioxide
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
ERT	AFCEE's Technology Transfer Division
FSA-1	Fuel Saturation Area No. 1
IDW	Investigation-derived waste
mg/kg	Milligrams per kilogram
mg/kg/year	Milligrams of hydrocarbons per kilogram of soil per year
MP	Monitoring point
MW	Monitoring well
O&M	Operations and maintenance
Parsons ES	Parsons Engineering Science, Inc.
ppmv	Parts per million, volume per volume
PVC	Polyvinyl chloride
RAP	Remedial Action Plan
scfm	Standard cubic feet per minute
TPH	Total petroleum hydrocarbons
TRPH	Total recoverable petroleum hydrocarbons
TVH	Total volatile hydrocarbons
UST	Underground storage tank
VOC	Volatile organic compounds
VW	Vent well

SECTION 1

INTRODUCTION

This document presents the remedial action plan for a full-scale bioventing system for *in situ* treatment of fuel-contaminated soils adjacent to Building 14, referred to as Fuel Saturation Area No. 1 (FSA-1), at Air Force Plant No. 4 (AFP4), Texas. The proposed activities will be performed by Parsons Engineering Science, Inc. (Parsons ES), formerly Engineering-Science, Inc. (ES), for the Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division (ERT) under contract F41624-92-D-8036, 0017.

The overall goal of the proposed full-scale bioventing system is to enhance biodegradation of fuels in the soil to minimize any contribution to groundwater contamination. Achieving this objective will decrease the amount of time required for long-term monitoring of the site and allow earlier site closure. The primary objectives of the system are:

- To enhance *in situ* remediation of anaerobic, source area, fuel-contaminated soils by injection of atmospheric air into these soils;
- To reduce the time span of the long-term monitoring requirements at FSA-1; and
- To sustain aerobic *in situ* biodegradation until hydrocarbon-contaminated soils within the unsaturated zone are remediated to below regulatory standards in the contamination source-area.

Although the AFP4 baseline risk assessment indicates that there is no unacceptable risk to human health or the environment from soil or groundwater contamination at FSA-1 (Rust, 1995), voluntary remedial actions were proposed to reduce the required long-term monitoring and to facilitate closure of the site. These voluntary actions include free-product recovery, groundwater extraction and treatment, and expansion of the existing (pilot-scale) bioventing system at FSA-1.

A 1-year bioventing pilot test was performed at a portion of FSA-1 from March 1993 to May 1994 to determine if *in situ* bioventing would be a feasible cleanup technology for the fuel-contaminated soils within the unsaturated zone. During this period, a radius of oxygen influence of at least 20 feet was observed at 5-, 14-, and 19-foot depths, at an average flow rate of 10 standard cubic feet per minute (scfm). Further information about the pilot test procedures and results can be found in Section 3 of this plan and in the Interim Pilot Test Results Report (ES, 1993).

Following the 1-year pilot test, soil and soil gas data indicated significant contaminant removal in the pilot-test area, with almost complete removal of benzene, toluene, ethylbenzene, and xylenes (BTEX). Soil BTEX concentrations were reduced from an average of 44 milligrams per kilogram (mg/kg) to non-detectable levels. Soil total recoverable petroleum hydrocarbon (TRPH) results were inconclusive, with both increases and decreases measured after 1 year of operation. Soil gas concentrations of total BTEX were reduced from an average of 41 parts per million, volume per volume (ppmv) to 1.2 ppmv across the site and total volatile hydrocarbons (TVH) were reduced from an average of 25,000 to 290 ppmv. The success of the pilot test at this site supports the recommendation of a full-scale bioventing system as the most economical approach of remediating the hydrocarbon-contaminated soils at FSA-1.

Pilot-test data were used to design the full-scale bioventing system. The proposed full-scale system consists of three air injection vent wells (VWs), three monitoring points (MPs), a blower system, and the associated controls and piping. This system is designed to deliver oxygen throughout the most highly contaminated unsaturated soils.

The selected location of the proposed full-scale bioventing system is at the south end of Building 14 in the vicinity of two former underground storage tanks (USTs), and south of the bioventing pilot-test area. This location was selected to remediate the most highly contaminated soils identified within the FSA-1 area. Because subsurface soil conditions at the proposed location are similar to those in the pilot-test area, design parameters determined from pilot-scale testing should be applicable to the new, full-scale bioventing system.

This document is divided into eight sections including this introduction. Section 2 discusses site background and includes a discussion of existing characterization data. Section 3 provides results of the 1-year pilot test. Section 4 identifies the treatment area of the proposed full-scale system; provides construction details of the full-scale system; and recommends a proven, cost-effective approach for remediation of the remaining hydrocarbon-contaminated soils. Investigation-derived waste disposal procedures are described in Section 5, and Plant support requirements are provided in Section 6. Section 7 provides key points of contact at AFP4, Wright-Patterson Air Force Base (AFB), AFCEE, and Parsons ES; and Section 8 provides the references cited in this document. A design package for the full-scale bioventing system is provided in Appendix A.

SECTION 2

SITE BACKGROUND

2.1 SITE LOCATION AND HISTORY

FSA-1 is located south and east of Building 14 (Figures 2.1 and 2.2). Soil and groundwater at this site reportably became contaminated with fuels and solvents leaking from two 12,000-gallon USTs (Tank Nos. 19 and 20) and underground JP-4 jet fuel distribution piping during the mid-1970s to the early 1980s (Rust, 1995). The two former USTs, which were located south of Building 14, were removed prior to December 22, 1988. These USTs contained 2-butanone (Tank 19) and xylenes (Tank 20). The JP-4 distribution piping was abandoned in 1988.

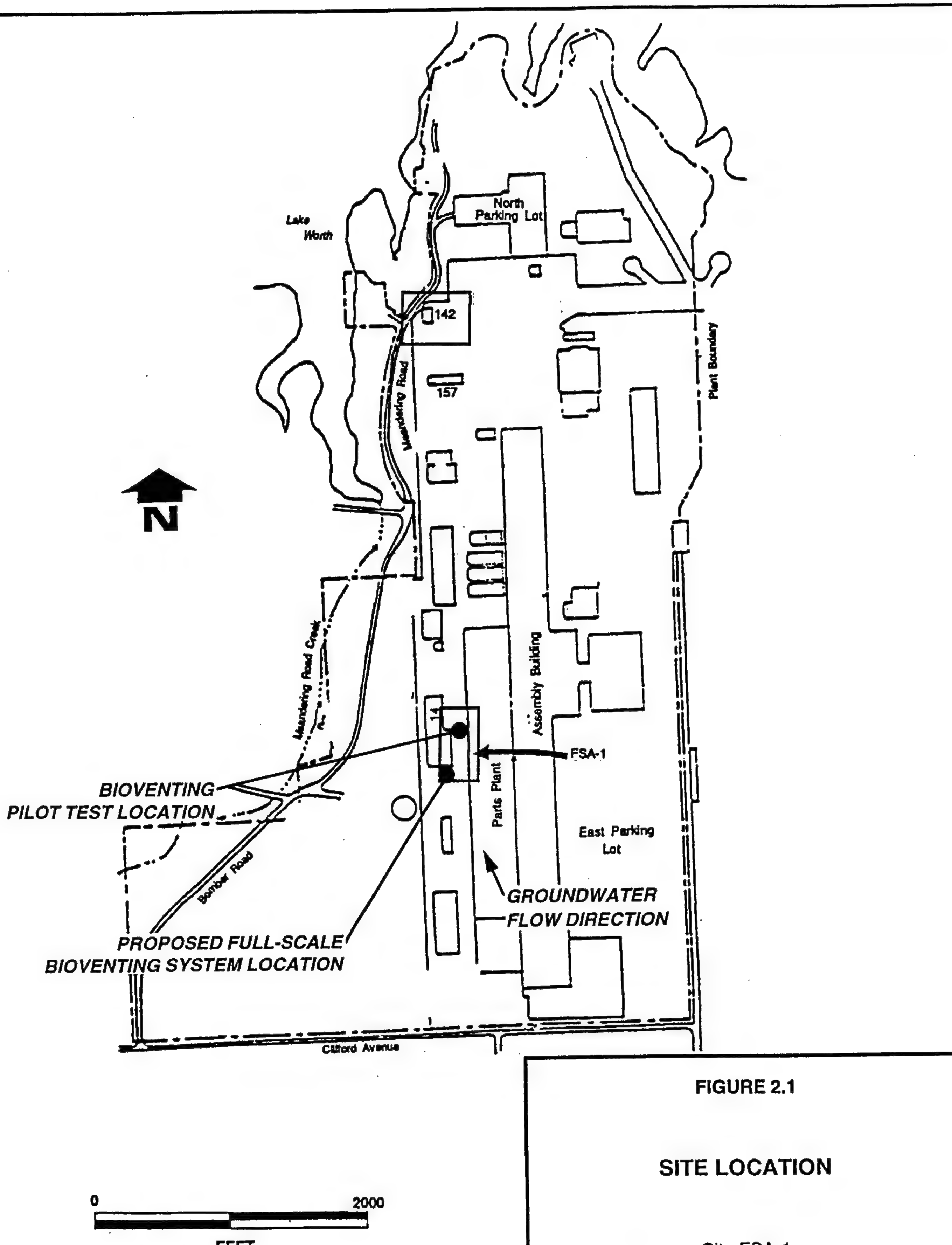
2.2 SITE HYDROGEOLOGY

Because bioventing technology is applied to unsaturated soils, this section will primarily discuss the soils above the groundwater surface. FSA-1 is underlain by approximately 30 feet of unconsolidated sediments which overlie the weathered shale of the Goodland Formation. The unconsolidated sediments are composed primarily of silty, sandy clay with layers and lenses of sand and sand/gravel mixtures. The average grain size generally increases with depth.

Groundwater at FSA-1 occurs predominantly in coarse-grained sediments at a depth of 20 to 22 feet below ground surface (bgs). The groundwater flow direction in this portion of AFP4 is generally toward the north and northwest. However, at the time of the most recent investigations (1991), groundwater in the vicinity of the former USTs was characterized by a nearly flat surface (Rust, 1995). A hydrogeologic cross-section of FSA-1, in the area of the former USTs, is provided in Figure 2.3.

2.3 SITE CONTAMINANTS

The primary soil contaminants at this site are fuel-related petroleum hydrocarbons and other volatile organic compounds (VOCs). The reported source of the contamination was the leaking USTs and associated piping, and in fact, the highest concentrations of contaminants in soils were detected in the vicinity of these former USTs (Rust, 1995). Figure 2.4 shows the results of VOC and total petroleum hydrocarbon (TPH) analyses for each borehole location. The highest TPH result for soil was 8,781 mg/kg in the sample collected at a depth of 20-25 feet bgs at borehole SB-133. The highest concentration of toluene [12,000,000 micrograms per kilogram



Sources: After Radian, 1987

FIGURE 2.1

SITE LOCATION

Site FSA-1
Air Force Plant No. 4, Texas

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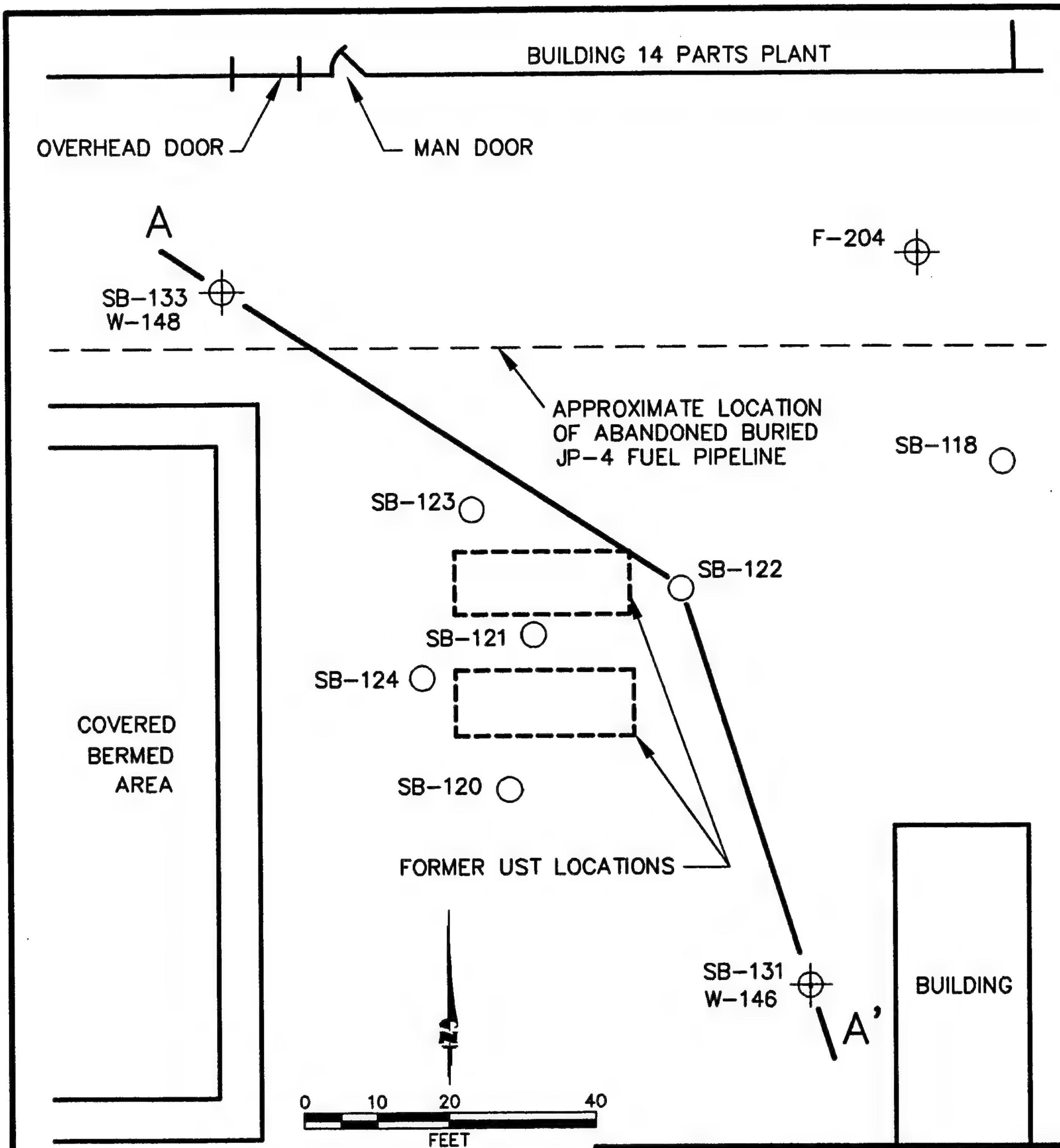

LEGEND

⌖ EXISTING GROUNDWATER MONITORING WELL (RUST, 1995)

○ EXISTING SOIL BOREHOLE (RUST, 1995)

NOTE:
CROSS-SECTION A-A' SHOWN ON FIGURE 2.3

FIGURE 2.2

SITE LAYOUT

Site FSA-1
Air Force Plant No. 4, Texas

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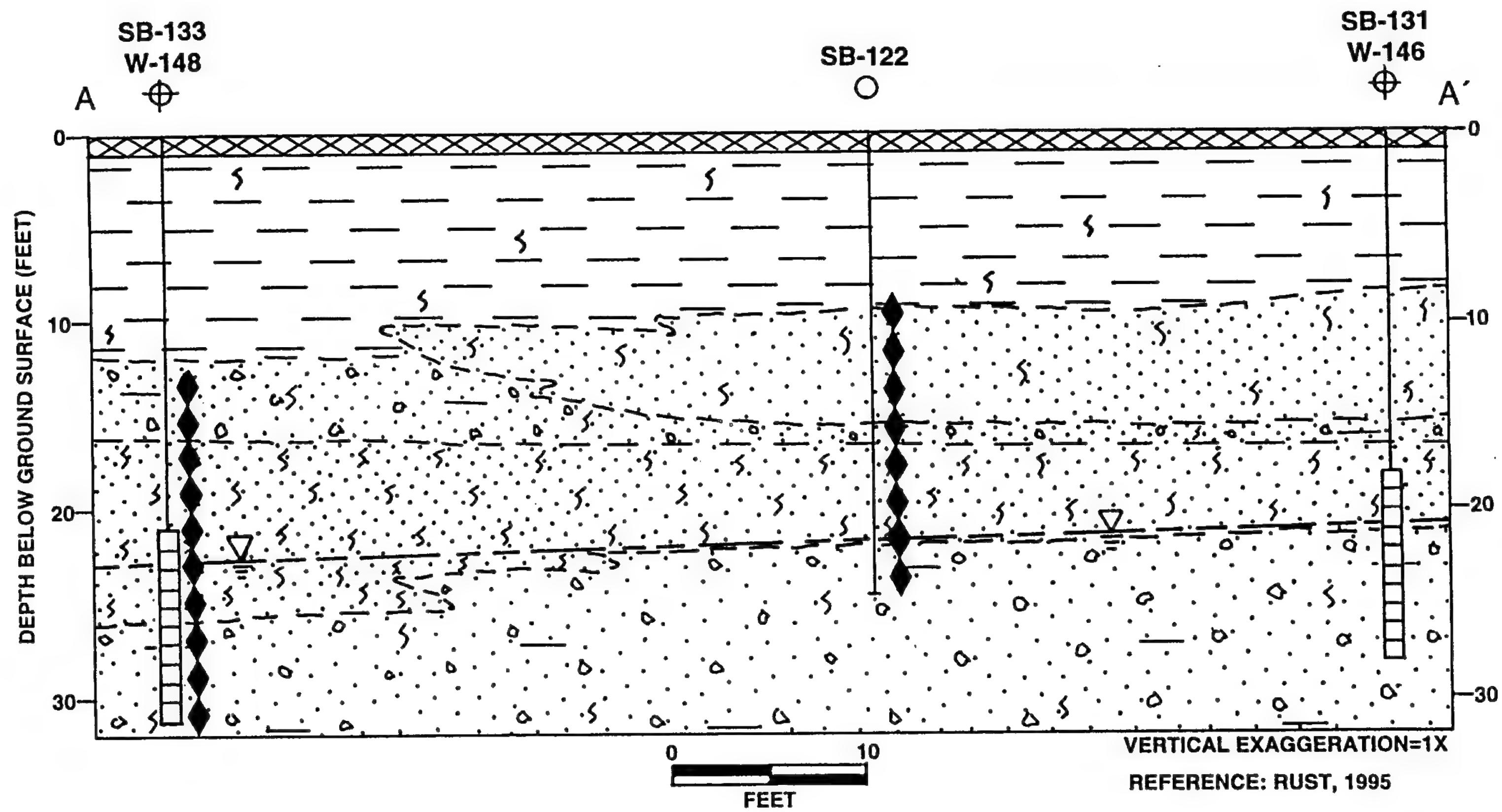

LITHOLOGIC DESCRIPTION

SILTY CLAY SILTY SAND CLAYEY, SILTY, SANDY GRAVEL ASPHALT

LEGEND

SB-133 W-148 MONITORING WELL

SB-122 SOIL BOREHOLE

FUEL ODOR DETECTED DURING DRILLING

GROUNDWATER SURFACE WHEN DRILLED

GEOLOGIC CONTACT, DASHED WHERE INFERRED

SCREENED WELL INTERVAL

FIGURE 2.3

HYDROGEOLOGIC CROSS-SECTION A-A'

Site FSA-1
Air Force Plant No. 4, Texas

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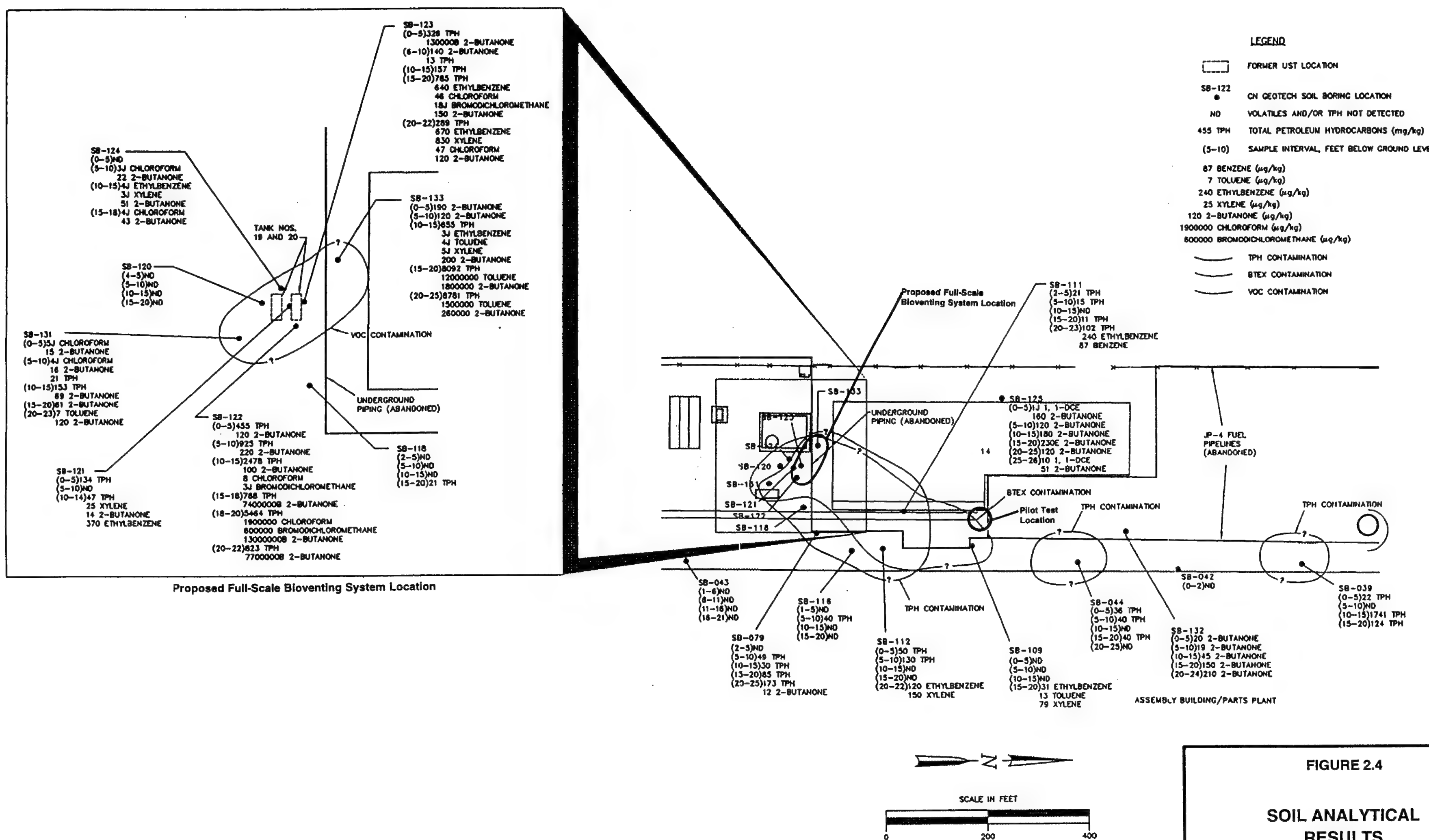

Source: RUST, 1995.

FIGURE 2.4

SOIL ANALYTICAL RESULTS

Site FSA-1
Air Force Plant No. 4, Texas

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Denver, Colorado

(μg/kg)] was also detected in borehole SB-133, but at 15 to 20 feet bgs. The highest concentrations of 2-butanone were detected in SB-122 (13,000,000 μg/kg) at 18 to 20 feet bgs and again in SB-133 (1,800,000 μg/kg) at 15 to 20 feet bgs.

Figure 2.5 indicates the approximate areal extent of soil VOC contamination in the vicinity of the former USTs. Also shown on the figure is the extent of soil VOC contamination exceeding 1.0 mg/kg targeted for remediation by the proposed full-scale bioventing system.

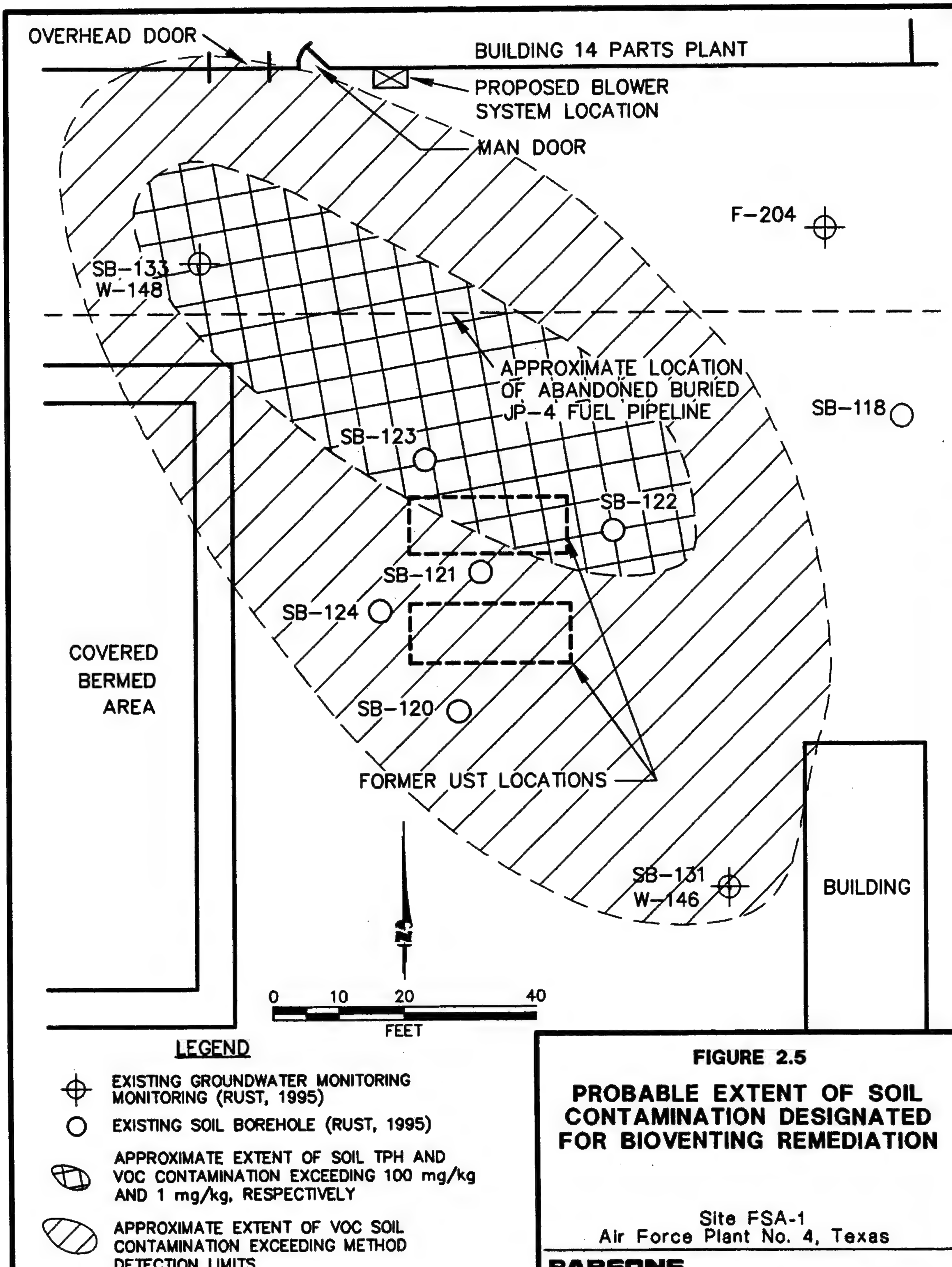

FIGURE 2.5

PROBABLE EXTENT OF SOIL CONTAMINATION DESIGNATED FOR BIOVENTING REMEDIATION

Site FSA-1
Air Force Plant No. 4, Texas

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

SECTION 3

BIOVENTING PILOT-TEST RESULTS

A bioventing pilot test was performed by Parsons ES from March 1993 to May 1994 as part of the AFCEE Bioventing Pilot Test Initiative contract. The objectives of the bioventing pilot test were to:

- Assess the potential for supplying oxygen throughout the contaminated soil profile;
- Determine the rate at which indigenous microorganisms will degrade petroleum hydrocarbons when stimulated by oxygen-rich soil gas; and
- Evaluate the potential for sustaining these rates of biodegradation until hydrocarbon contamination is remediated below regulatory standards.

3.1 PILOT-TEST CONFIGURATION

The pilot-scale test system was installed by Parsons ES in March 1993 at FSA-1, and consisted of an air injection VW and three MPs. The pilot-test location and configuration were based on site investigation data (Chem-Nuclear Geotech, Inc., 1992), which indicated that the highest TPH contamination was in the vicinity of the abandoned underground JP-4 jet fuel pipeline [Monitoring well (MW) F-205]. As shown on Figure 3.1, the VW was placed on the east side of Building 14 and south of MW F-205. The three MPs were positioned 5, 10, and 20 feet south of the VW to monitor *in situ* biodegradation rates and to determine the radius of oxygen influence and pressure response resulting from air injection at the VW.

During drilling, hydrocarbon-contaminated soils were encountered between approximately 12 and 23 feet bgs. Groundwater was measured at 20.5 feet bgs. The air injection VW was screened from 8 to 23 feet bgs to maximize aeration in the fuel-contaminated vadose zone (unsaturated) soil. The screened interval was extended into the top of groundwater to allow for seasonal fluctuations. Screened intervals were placed at 5, 14, and 19 feet bgs in each MP.

3.2 INITIAL SOIL GAS MEASUREMENTS

Prior to any pilot-test activities, initial oxygen, carbon dioxide, and TVH concentrations were measured with portable field instruments. Initial oxygen levels were depleted (less than 1 percent oxygen at all MP screened intervals and 3.5 percent oxygen at the VW), and carbon dioxide (CO_2) levels were elevated (5.5 to 12.5 percent

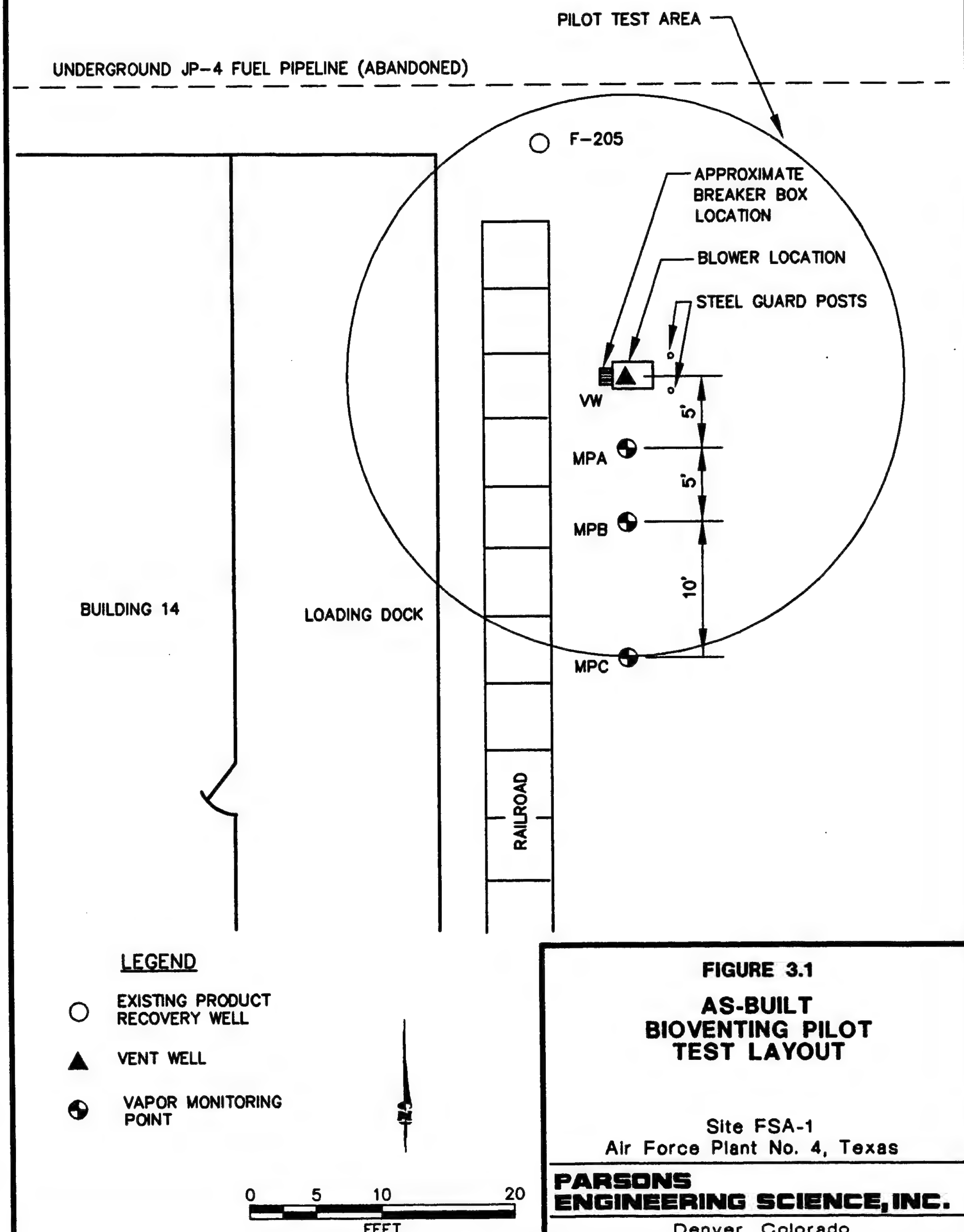

FIGURE 3.1

AS-BUILT BIOVENTING PILOT TEST LAYOUT

Site FSA-1
Air Force Plant No. 4, Texas

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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CO_2 in both MP and VW soil gas samples). In contrast, soil gas from the background MP (Well FSA3-8 located approximately 3,000 feet north of FSA-1) contained oxygen at a concentration of 16 percent and CO_2 at a concentration of 3.5 percent. These initial levels indicated that oxygen depletion and CO_2 accumulation resulted from biodegradation of hydrocarbon contaminants rather than naturally occurring organic matter and abiotic processes.

3.3 *IN SITU* BIODEGRADATION RATES

In situ respiration testing was then conducted to determine the biodegradation rates of indigenous bacteria in contaminated subsurface soils. Table 3.1 shows the results of three *in situ* respiration testing events conducted at the outset, after 6 months, and after 1 year of the pilot-test.

Initial biodegradation rates ranged from 300 to 1,600 milligrams of TRPH per kilogram of soil per year (mg/kg/year) and averaged 650 mg/kg/year. The faster biodegradation rates corresponded to depth intervals with higher TPH concentrations. After 6 months of continuous air injection, biodegradation rates decreased to an average of 103 mg/kg/year, despite warmer soil temperatures. At the end of the 1-year testing period, the rates had declined to 93 mg/kg/year. This decline in biodegradation rates is likely due to the reduction of petroleum hydrocarbons remaining in the soils.

3.4 AIR PERMEABILITY/OXYGEN INFLUENCE

An air permeability/radius of oxygen influence test was performed to determine the pressure response in the soil profile induced by air injection at the VW, and to determine the volume of subsurface soils that could be oxygenated from this single VW.

Air was injected into the VW for approximately 50 hours at a rate of approximately 10 scfm and an average pressure of approximately 72 inches of water. Following the air permeability test, air was injected for an additional 21 hours to obtain a more accurate estimate of the radius of oxygen influence. The dynamic method was used to calculate soil gas permeability values, which averaged 0.6 darcys. The pressure response measured at each MP screened interval increased at irregular rates throughout the period of air injection.

Oxygen level increases were measured at the VW and in all screened intervals of the MPs. Based on these results and the measured pressure response, the effective treatment radius of a long-term bioventing system at this site should exceed 35 feet at all depths. Oxygen measurements taken after 6-months and 1-year of testing confirmed that the radius of oxygen influence exceeds 20 feet. Therefore, for design purposes, a 25-foot radius was selected.

3.5 SOIL AND SOIL GAS SAMPLING RESULTS

Soil and soil gas samples were collected during installation of the pilot-scale bioventing system in March 1993 to determine baseline contaminant concentrations at

TABLE 3.1
SITE FSA-1
RESPIRATION AND DEGRADATION RATES
AIR FORCE PLANT 4, TEXAS

	Initial			6-Month [b/]			1-Year		
Location-Depth	K_o (% O_2/min)	Degradation Rate (mg/kg/year)[a/]	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)	K_o (% O_2/min)	Degradation Rate (mg/kg/year)	Soil Temperature (°C)
VW	0.0028	340	NM[c/]	0	0	NM	NC[d/]	NC	NM
MPA-5	0.0025	300	15.7	0.00054	60	26.4	NC	NC	24.6
MPA-14	0.0026	310	NM	0.00045	50	NM	NC	NC	NM
MPA-19	0.0094	1100	20.8	0.0022	240	24.4	0.0016	160	21.4
MPB-5	0.0035	560	NM	0.0010	120	NM	NC	NC	NM
MPB-14	0.010	1600	NM	0.00049	60	NM	0.00048	40	NM
MPB-19	0.0074	1200	NM	0.0017	210	NM	0.0011	90	NM
MPC-5	0.0044	310	NM	0.00087	80	NM	NC	NC	NM
MPC-14	0.0042	300	NM	0.00060	50	NM	0.00075	80	NM
MPC-19	0.0073	510	NM	0.0018	160	NM	NC	NC	NM

[a/] Milligrams of hydrocarbons per kilogram of soil per year.
Note: Differences between these rates and those presented in the Interim Report (ES, 1993) are the result of rounding corrections.

[b/] Assumes moisture content of the soil is average of the initial and final readings.

[c/] NM = Not measured.

[d/] NC = Not calculated; final respiration test not performed at this monitoring point.

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the VW and MP locations. Samples were collected from the same locations in May 1994, after approximately 1 year of pilot-scale soil treatment. The bioventing system was turned off for 10 days prior to collecting these 1-year soil gas samples to allow the soil gas to reach equilibrium with any remaining fuel contamination in the unsaturated soil. Sampling results are shown on Table 3.2. These results indicate that significant reductions in hydrocarbon concentrations occurred during the 1-year study.

As shown in Table 3.2, soil and soil gas data indicate significant contaminant removal in the pilot-test area, with an almost complete removal of BTEX compounds. Based on laboratory results from soil and soil gas samples collected from the most contaminated areas, total BTEX concentrations in soil were reduced from an average of 44 mg/kg to non-detectable levels. Soil TRPH results were mixed, with increases and decreases measured after 1 year of system operation. The measured increases may have been the result of nonhomogeneous distribution of TRPH in the soil combined with a small number of discrete samples; or the result of fluctuating groundwater recharging the unsaturated zone with additional petroleum hydrocarbons. Soil gas contaminant concentrations of TVH were reduced from an average of 25,000 ppmv to 290 ppmv. Total BTEX was reduced from an average of 41 ppmv to 1.2 ppmv across the site during the one-year period. These reductions are likely due to enhanced biodegradation resulting from soil oxygenation, along with minor amounts of volatilization. The success of bioventing at this site supports the recommendation of a full-scale bioventing system as the most economical approach to remediating the hydrocarbon-contaminated soils at FSA-1.

3.6 RECOMMENDATIONS FOR FULL-SCALE BIOVENTING

Based on the successful results of the 1-year bioventing pilot test, AFCEE has provided funding for the design and installation of a full-scale bioventing system at FSA-1. AFCEE has retained Parsons ES to continue providing bioventing services at AFP4 and to complete the design and installation of the full-scale system.

Based on the initial pilot-test results, available analytical data, and recently completed soil gas screening at FSA-1 (Figure 3.2), Parsons ES has prepared a full-scale bioventing system design which will employ three new VWs and an estimated three additional MPs. The three new MPs will be installed to monitor soil gas chemistry and pressure response to ensure that oxygen is being effectively delivered to contaminated soils. Section 4 provides details on the design, construction, and operation of the full-scale system. A design package has also been prepared for construction of the system, and is included in Appendix A.

Although the bioventing pilot test was performed in an area located east of Building 14, the proposed full-scale bioventing system will be located south of Building 14, adjacent to the locations of the two former USTs. The former UST location was chosen over the pilot-test location because soil contamination near the USTs is much greater than at the pilot-test location.

Logs for the soil boreholes adjacent to the former USTs indicate that subsurface conditions at the UST site are similar to those at the pilot-test location. These similarities indicate that the design parameters determined during pilot-scale testing,

TABLE 3.2
SITE FSA-1
SOIL AND SOIL GAS ANALYTICAL RESULTS
AIR FORCE PLANT 4, TEXAS

Analyte (Units)[a]	Sample Location-Depth (feet below ground surface)					
	VW		MPA-19		MPC-14	
Soil Gas Hydrocarbons	Initial[b]	1-Year[c]	Initial	1-Year	Initial	1-Year
TVH (ppmv)	17,000	19	26,000	640	32,000	220
Benzene (ppmv)	ND	0.026	ND	0.40	ND	0.29
Toluene (ppmv)	ND	0.010	ND	0.24	ND	0.033
Ethylbenzene (ppmv)	24	0.031	16	0.56	24	0.086
Xylenes (ppmv)	26	0.13	18	1.7	14	0.18
	MPA-18		MPB-18		MPC-15	
Soil Hydrocarbons	Initial[d]	1-Year[e]	Initial	1-Year	Initial	1-Year
TRPH (mg/kg)	73	2040	12	7.4	ND	ND
Benzene (mg/kg)	ND	ND	ND	ND	0.041	ND
Toluene (mg/kg)	1.5	ND	2.3	ND	0.0045	ND
Ethylbenzene (mg/kg)	12	ND	23	ND	0.052	ND
Xylenes (mg/kg)	30	ND	64	ND	0.033	ND
Moisture (% by wt.)	13.4	14.6	11.6	15.5	16.2	13.9

[a] TRPH = total recoverable petroleum hydrocarbons; mg/kg = milligrams per kilogram;
TVH = total volatile hydrocarbons; ppmv=parts per million, volume per volume.
[b] Initial soil gas samples collected on 03/06/93.
[c] 1-Year soil gas samples collected on 05/23/94.
[d] Initial soil samples collected on 03/05/93.
[e] 1-Year soil samples collected on 05/26/94.

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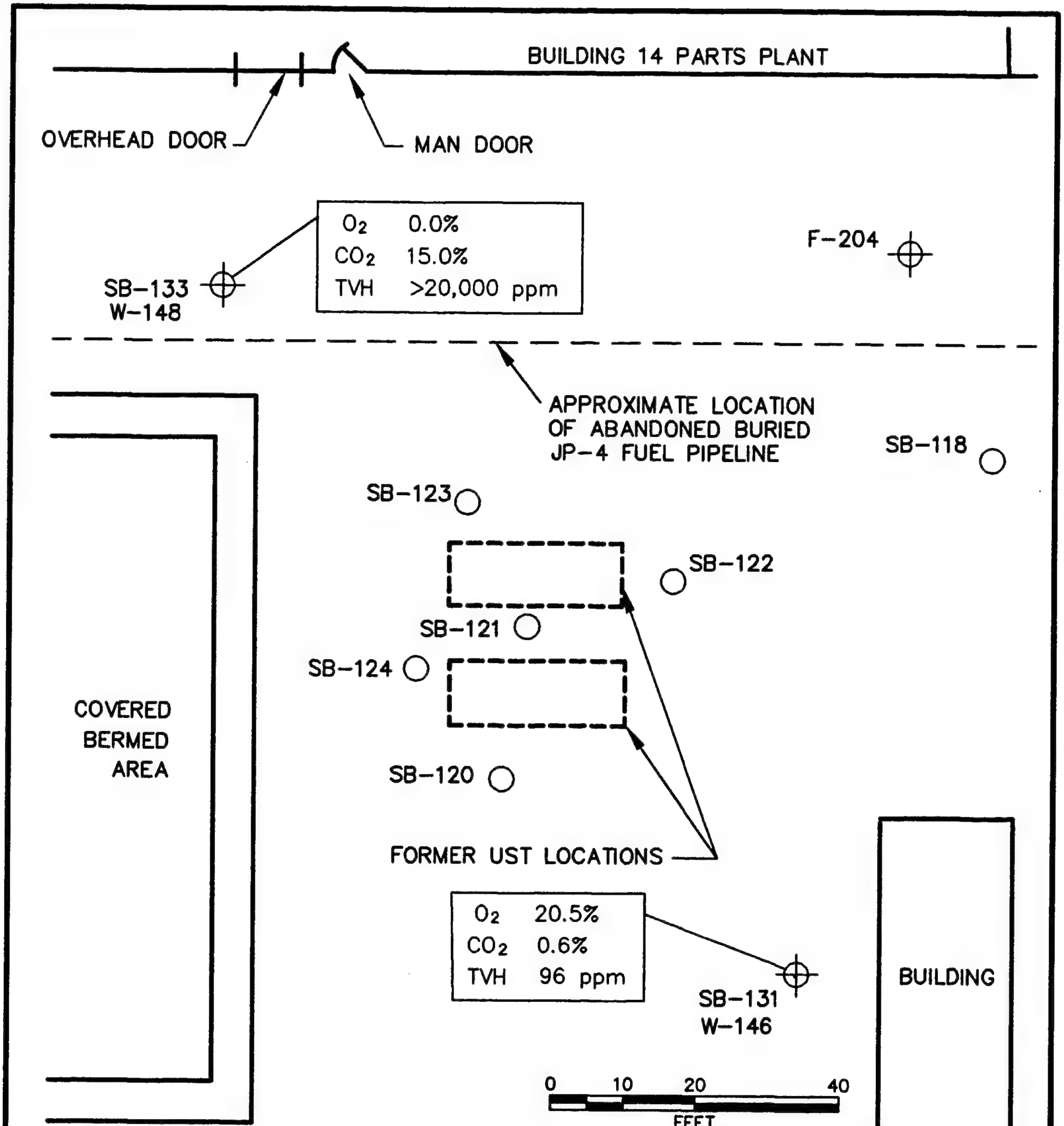


LEGEND

⌖	EXISTING GROUNDWATER MONITORING WELL (RUST, 1995)
○	EXISTING SOIL BOREHOLE (RUST, 1995)
O_2 20.5%	PERCENT OXYGEN
CO_2 0.6%	PERCENT CARBON DIOXIDE
TVH	TOTAL VOLATILE HYDROCARBONS (PARTS PER MILLION)

N

FIGURE 3.2

INITIAL SOIL GAS SAMPLING RESULTS

Site FSA-1
Air Force Plant No. 4, Texas

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

such as permeability and effective treatment radius, will be applicable to the design of the full-scale system. Additionally, soil gas samples collected by Parsons ES on November 16, 1995 from well W-148 (and discussed further in Section 4) had total volatile hydrocarbon (TVH) concentrations exceeding 20,000 ppmv and were depleted in oxygen (less than 1 percent), indicating that air injection (bioventing) will enhance biodegradation of fuel-related hydrocarbons by supplying oxygen to the contaminated soils.

SECTION 4

FULL-SCALE BIOVENTING SYSTEM

The purpose of the full-scale bioventing system is to provide oxygen to stimulate aerobic biodegradation of the remaining soil contamination in the vicinity of the two former USTs. System design details are provided in Appendix A.

4.1 OBJECTIVES

The primary objectives of the full-scale bioventing system are to:

- Fully aerate areas at the site designated for bioventing remediation;
- Eliminate the potential for contamination to migrate and adversely affect groundwater quality at the site by removing the contaminant source from vadose zone soils;
- Minimize the duration of long-term ground water monitoring required at the site; and
- Provide the most cost-effective remediation alternative for this site.

4.2 BASIS OF DESIGN

Soil gas sampling was performed by Parsons ES on November 16, 1995 to determine if soil gas in the vicinity of the former USTs was depleted of oxygen. Soil gas samples were extracted from existing groundwater MWs W-146 and W-148, which were constructed with several feet of well screen extending above the groundwater surface. Sampled MWs were purged, and soil gas oxygen, CO_2, and TVH concentrations were measured using portable gas analyzers, as described in the technical protocol document (Hinchee *et al.*, 1992). Soil gas from MW W-146 (outside the area of significant soil contamination) had oxygen and carbon dioxide concentrations of 20.5 and 0.6 percent, respectively, and a TVH concentration of 96 ppmv. In contrast, soil gas from W-148 (located within the area of previously identified soil contamination) had oxygen and CO_2 concentrations of 0.0 and 15 percent, respectively, and a TVH concentration greater than 20,000 ppmv, indicative of significantly contaminated soils and high biological activity. Air injection VWs will be placed in these oxygen-depleted soils to aerate contaminated zones and stimulate aerobic biodegradation.

4.3 SYSTEM DESIGN

The proposed full-scale bioventing system will include a blower system, three VWs, three MPs, and associated piping and controls. The monitoring points will be constructed to monitor soil gas at the site. The three VWs will be installed across the site to ensure proper oxygenation of unsaturated soil throughout the area of the presumed soil contamination. The new VWs will be 4 inches in diameter and will be screened with 0.040-inch slot from approximately 5 to 20 feet bgs. Figure 4.1 shows the proposed locations of the VWs and MPs along with the estimated radius of influence for each VW.

The VWs will be manifolded using 2-inch-diameter, Schedule 80 polyvinyl chloride (PVC) as the conduit through which the injected air will flow from the blower to the proposed VWs. The piping will be set at a minimum depth of 18 inches bgs and will be connected to a 2.5-horsepower regenerative blower. A separate flow control valve and flow measurement port will be included in the line connecting each VW to measure and adjust the air flow to the VWs. The blower and valving will be housed in a weatherproof enclosure for protection from the elements and for security purposes.

Trenchline configuration, blower location, and other design details are in Appendix A.

4.4 CONSTRUCTION SCHEDULE

Following review and approval of this plan by AFCEE/ERT, AFP4, and Wright-Patterson AFB, field work will begin. The following schedule is contingent upon timely approval of this plan:

Event	Date
Draft Remedial Action Plan (RAP) and Design Package to AFCEE/ERT, AFP4, and Wright-Patterson AFB	February 12, 1996
Final RAP and Design Package to AFCEE/ERT, AFP4, and Wright-Patterson AFB	March 1, 1996
Begin Field Activities and Construction of Full-Scale Bioventing System	March 4, 1996
Complete Construction and System Startup	March 15, 1996

4.5 SYSTEM OPERATION, TESTING, AND MONITORING

Following system installation, baseline respiration testing will be performed, and an operations and maintenance (O&M) manual, and as-built system drawings will be prepared.

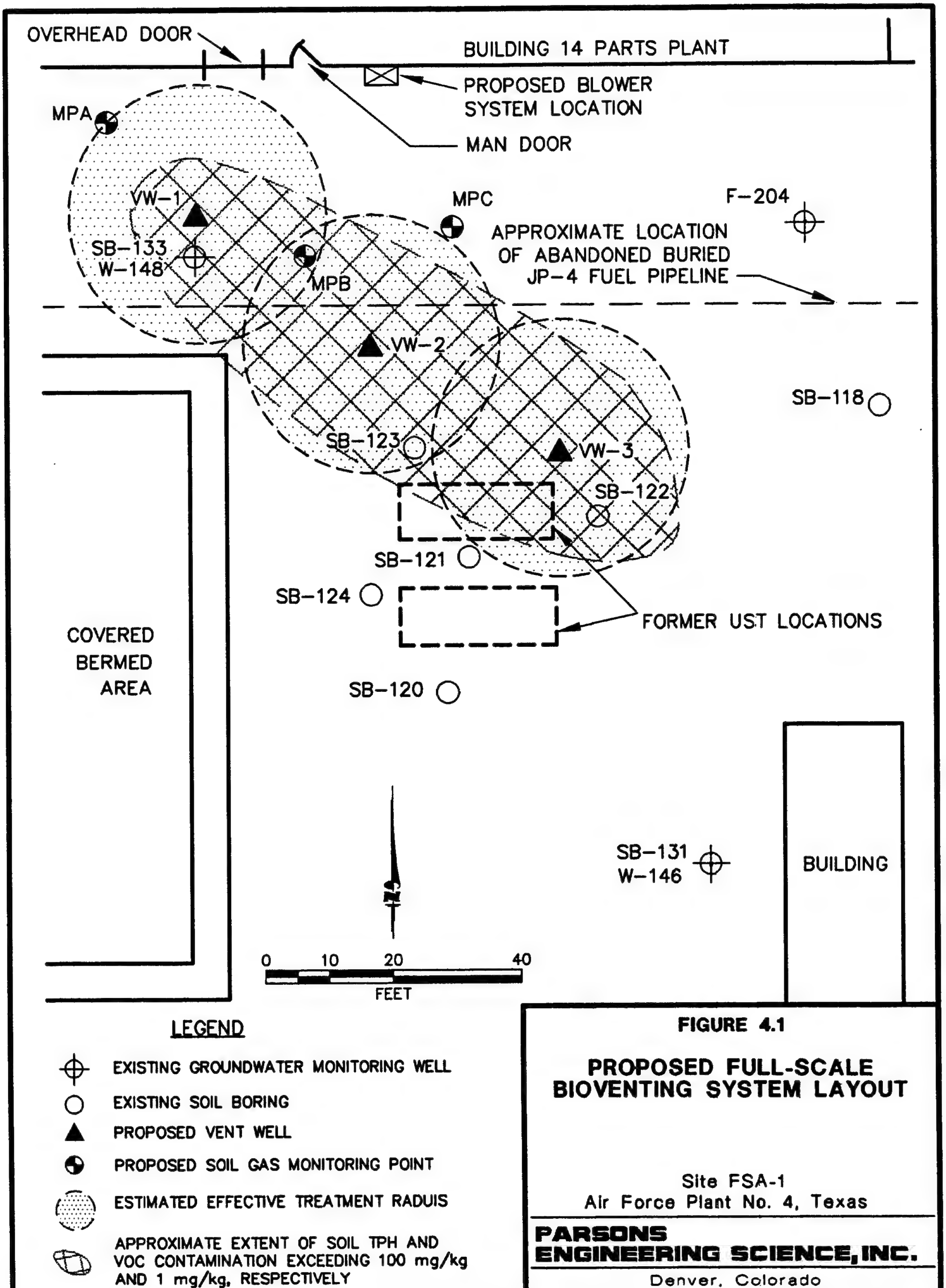


FIGURE 4.1

PROPOSED FULL-SCALE BIOVENTING SYSTEM LAYOUT

Site FSA-1
Air Force Plant No. 4, Texas

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

4.5.1 Baseline Testing and Sampling

In situ respiration testing will be performed at selected MP screened intervals following procedures described in the protocol document (Hinchee *et al.*, 1992), with the exception that helium tracer gas will not be used. Because the proposed full-scale bioventing system is located more than 300 feet from the bioventing pilot-test area, respiration testing will be performed to confirm that adequate biodegradation is occurring at the full-scale site. *In situ* respiration testing will be conducted by injecting air into selected MP screened intervals with depleted soil gas oxygen concentrations and measuring the decrease in oxygen due to biological respiration over a period of approximately 2 days.

Five soil samples will be collected during installation activities. One sample will be collected from the most contaminated zone encountered in boreholes drilled for all three MPs and two of the three new VWs. Soil samples will be analyzed for BTEX and TRPH by using U.S. Environmental Protection Agency (EPA) Methods SW8020 and SW8015, respectively.

Prior to system startup, soil gas samples will be collected from all MP intervals and field-screened to establish baseline oxygen, CO_2, and TVH levels. Based on field-screening results, the five most contaminated MP intervals (highest TVH) will be identified and soil gas samples collected from each for laboratory analysis of TVH and BTEX concentrations (EPA Method TO-3).

4.5.2 System Operation and Maintenance

At startup of the full-scale system, it will be necessary to optimize the air injection rates and to ensure proper operation of the blower system. Flow rate optimization is accomplished by gradually increasing the flow rate to each VW until soil gas oxygen concentrations at all MP depth intervals reach a minimum of approximately 10 percent. Oxygen levels in excess of 10 percent at the outer MPs may indicate that the volume of air passing through the soil exceeds biological oxygen utilization. The blower will be monitored to ensure that it is producing the required flow rate and pressure for air injection.

Operation and maintenance (O&M) requirements for the proposed full-scale bioventing system are minimal. The regenerative blower is virtually maintenance-free. The only recurring maintenance required will be a monthly check of the air filter, which is generally replaced when a pressure difference of 10 to 15 inches of water across the inlet filter is reached. The time period between filter changes depends on site conditions, and is typically 3 to 6 months. The O&M manual will contain further details of operation requirements.

4.5.3 System Monitoring

Monitoring of the bioventing system will include checking the blower operation, including outlet pressures, inlet vacuum, and exhaust temperature every 2 weeks. These checks will be performed by AFP4 technicians.

Parsons ES will visit the site after 1 year of operation to conduct a comprehensive system check to ensure that oxygen continues to reach all MPs in the contaminated soils. A 1-year *in situ* respiration test at the MPs will also be performed to ensure that biodegradation is continuing at acceptable levels. Additionally, soil gas samples will be collected from the same MP intervals which were initially determined to be most contaminated (prior to system startup) and re-analyzed for BTEX and TVH using EPA Method TO-3.

Prior to performing the 1-year respiration tests and soil gas sampling, the blower will be turned off for 30 days to allow soil gas to equilibrate with the fuel contamination remaining in the soil so that the 1-year data can be compared to initial soil gas data. Following soil gas sampling, air will be injected into VWs or MPs for 20 hours, and then shut off. Oxygen uptake will be monitored in the MPs for approximately 72 hours to measure the rate at which oxygen decreases in the soil gas. These data will then be used to estimate the current biodegradation rates and to evaluate the progress of contaminant removal and system effectiveness. As the fuel in the soil is depleted, the respiration activity of the indigenous microorganisms is reduced, and slower oxygen utilization rates result. Use of oxygen utilization rates and soil gas chemistry as indicators of remaining contaminant concentration decreases the likelihood of premature and costly soil sampling events in an attempt to attain site closure.

System monitoring and *in situ* respiration test data will be analyzed to determine the progress of soil remediation. Estimates of contaminant reduction and time remaining to complete soil remediation will be based on the data collected during the respiration tests (oxygen utilization rates), quantitative estimates of the long-term biodegradation rates, and decreases in soil gas concentrations.

4.5.4 Air Monitoring

The site and adjacent areas will be screened using direct-reading field instruments to confirm that fugitive VOC vapors are not produced by air injection at the VWs. VOC concentrations in air in the adjacent storm drain inlet and in the breathing zone within Building 14 will be measured before and during air injection. Monitoring will be performed a minimum of twice per day during system startup and testing, and again after approximately 1 week of system operation. If VOC concentrations are above pre-start-up levels, AFP4 personnel will be notified and appropriate action will be taken.

SECTION 5

HANDLING OF INVESTIGATION-DERIVED WASTES

Investigation-derived waste (IDW), consisting of drill cuttings generated during drilling operations and any contaminated soil generated during trenching activities, will be placed into 55-gallon, U.S. Department of Transportation (DOT)-approved containers and staged at the AFP4 drum storage area. The containers will be properly labeled indicating the nature of the contents, collection date, responsible party, and collection site location. Contaminated drill cuttings and other contaminated soil presently in the drum storage area will be disposed of in accordance with proper procedures. Clean soil and concrete removed during trenching operations will be removed from the site and disposed of by the drilling/construction subcontractor.

Decontamination water will be collected in 55-gallon, DOT-approved containers and staged at the AFP4 drummed water staging area. The containers will be properly labeled indicating the nature of the contents, collection date, and location of the collection site. (Water containing detergent will be segregated from the remaining decontamination water because it requires special treatment and disposal). Decontamination water will be disposed of along with other decontamination and purge water stored at the staging area in accordance with proper procedures.

SECTION 6

PLANT SUPPORT REQUIREMENTS

The following Plant support is needed prior to the arrival of the drilling subcontractor and the Parsons ES bioventing team:

- Assistance in obtaining drilling and digging permits;
- Gate passes, security badges, and vehicle passes (as necessary) for the Parsons ES bioventing team and for drilling and construction subcontractor personnel; and
- Guidance for management of IDW.

During system installation and baseline testing, the following Plant support is needed:

- A decontamination area where the driller can clean augers between borings; and
- A potable water supply for well construction and decontamination activities.

During the first year of operation, Base personnel will be required to perform the following activities:

- Check the blower system once every 2 weeks to ensure that it is operating, and to record the air injection pressure and other parameters. Parsons ES will provide a brief training session on this procedure.
- If the blower stops working, notify Mr. John Hall (970) 244-8829 or Mr. John Ratz (303) 831-8100 of Parsons ES; or Mr. Sam Taffinder (AFCEE) at (210) 536-4366.
- Arrange site access for a Parsons ES technician to conduct respiration testing and soil gas sampling approximately 1 year after system installation.

SECTION 7

KEY POINTS OF CONTACT

Mr. Luke Gilpin
Lockheed Martin
1500 Lockheed Blvd.
Ft. Worth, TX 76108
(817) 777-8203

Mr. John Doepker
ASC/EMR
Building 8
1801 Tenth Street, Suite 2
Wright-Patterson AFB, OH 45433-7626
(513) 255-7716

Mr. Sam Taffinder
AFCEE/ERT
8001 Arnold Drive
Brooks AFB, TX 78235-5357
DSN 240-4366
COM (210) 536-4366

Lt. Maryann Jenner
AFCEE/ERT
8001 Arnold Drive
Brooks AFB, TX 78235-5357
DSN 240-5688
COM (210) 536-5688

Mr. John Ratz
Parsons Engineering Science, Inc.
1700 Broadway, Suite 900
Denver, CO 80290
(303) 831-8100
Fax (303) 831-8208

Mr. John Hall
Parsons Engineering Science, Inc.
257 A 28 Road
Grand Junction, CO 81503
(970) 244-8829
Fax (970) 244-8829

SECTION 8

REFERENCES

Chem-Nuclear Geotech, Inc. 1992. *U.S. Air Force Plant No. 4 Draft Preliminary Assessment/Site Inspection and Remedial Investigation Report.* August.

Engineering-Science, Inc. 1993. *Draft Interim Pilot Test Results Report for FSA 1 and FSA 3, Air Force Plant 4, Texas.* May.

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* Prepared for USAF Center for Environmental Excellence. May

Rust Geotech, Inc. 1995. *Air Force Plant 4 Remedial Investigation and Preliminary Assessment/Site Inspection Report.* September.

APPENDIX A
DESIGN PACKAGE

CONSTRUCTION DRAWINGS FOR

FULL-SCALE BIOVENTING SYSTEM
SITE FSA-1
AIR FORCE PLANT 4, TEXAS

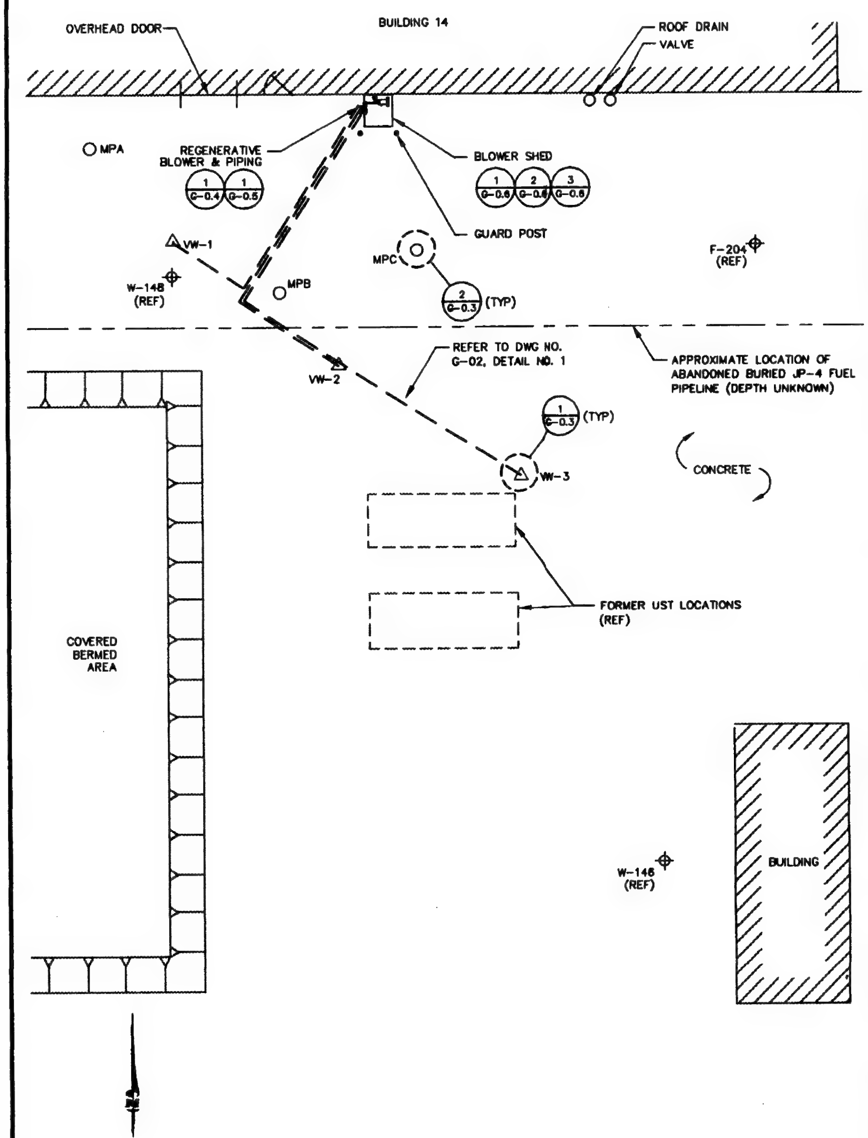
PREPARED FOR

AFCEE

FEBRUARY 1996

DRAWING INDEX

DRAWING NO	DRAWING NAME
G-0.1	TITLE SHEET AND SITE LAYOUT
G-0.2	LEGEND AND STANDARD TRENCH DETAILS
G-0.3	VENT WELL AND MONITORING POINT STANDARD DETAILS
G-0.4	BLOWER P & ID
G-0.5	BLOWER PIPING LAYOUT DETAIL
G-0.6	BLOWER SHED FIELD INSTALLATION DETAIL AND BLOWER SHED CONSTRUCTION DETAIL
G-0.7	TRAFFIC ROUTES DURING SYSTEM INSTALLATION



SITE LAYOUT

SCALE: 1" = 20'

Job No.	726876.17142
Designed	RAF
Drawn	BTP
Checked	2/29/96
Reviewed	
Approved	
Reg No	
Date	

Rev	Date	Description	By
A	1/31/96	65% DESIGN	

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AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)
FULL-SCALE BIOVENTING SYSTEM
SITE FSA-1
AIR FORCE PLANT 4, TEXAS

TITLE SHEET AND SITE LAYOUT

DRAWING NO: G-0.1 REV: A

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ABBREVIATIONS

AIJ	AIR INJECTION
APPROX	APPROXIMATE
ASTM	AMERICAN SOCIETY OF TESTING AND MATERIALS
&	AND
@	AT
CBM	CENTER BACK MOUNT
CLR	CLEAR
DIA	DIAMETER
EB	EXPLORATORY BORING
ECC	ECCENTRIC
EW	EACH WAY
FOT	FLAT ON TOP
FPT	FEMALE PIPE THREAD
FT	FOOT
GALV	GALVANIZED STEEL
HDPE	HIGH DENSITY POLYETHYLENE
ie	FOR EXAMPLE
LM	LOWER MOUNT
MAX	MAXIMUM
MIN	MINIMUM
MP	MONITORING POINT
MPT	MALE PIPE THREAD
NO, #	NUMBER
NPT	NATIONAL PIPE THREAD
NTS	NOT TO SCALE
OC	ON CENTER
OD	OUTSIDE DIAMETER
PVC	POLYVINYL CHLORIDE
PW	PROPOSED WELL
RED	REDUCER
REF	REFERENCE
SCH	SCHEDULE
S	SOCKET
SPVC	SLOTTED POLYVINYL CHLORIDE
ST STL	STAINLESS STEEL
TYP	TYPICAL
UST	UNDERGROUND STORAGE TANK
VW	VENT WELL
W/	WITH
WN	WELD NECK
WWF	WELDED WIRE FABRIC

SYMBOLS

F-204	EXISTING MONITORING WELL
MPC	PROPOSED BIOVENTING MONITORING POINT
VW-1	PROPOSED VENT WELL
— — —	PROPOSED HEADER PIPE TO VENT WELL
	BERM AND SLOPE

SECTION DESIGNATION — SECTION NAME

A / X — **SECTION CUT**

SCALE: NTS

DRAWING OF ORIGIN — SCALE

DETAIL NO — DETAIL NAME

1 / X — **DETAIL DESCRIPTION**

SCALE: NTS

DRAWING OF ORIGIN — SCALE

MATERIAL LEGEND

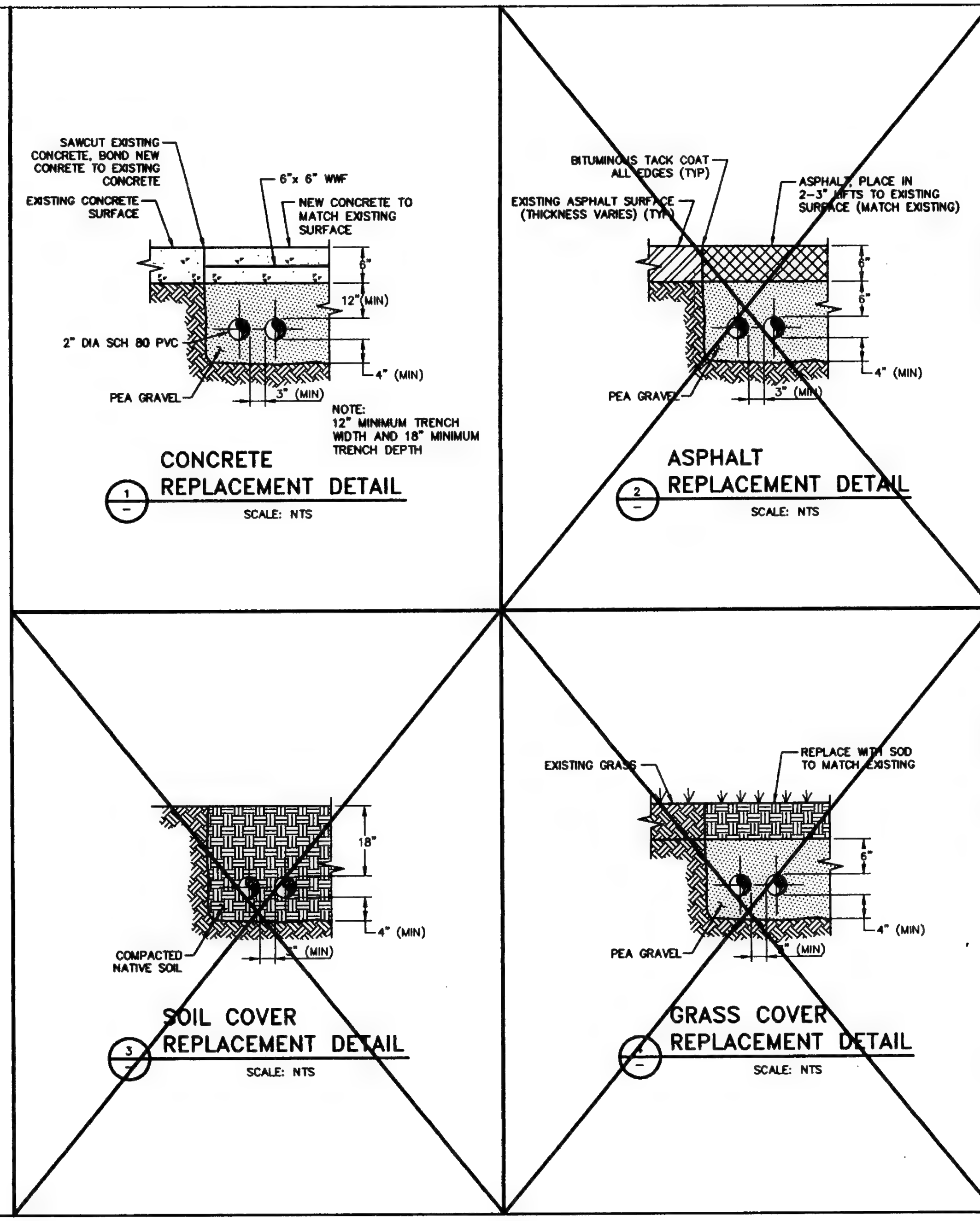
- ASPHALT
- BENTONITE
- BENTONITE/CEMENT GROUT
- BENTONITE PELLETS
- BUILDING (EXISTING)
- COMPACTED BACKFILL
- COMPACTED BASE STONE
- CONCRETE
- PEA GRAVEL
- SAND
- UNDISTURBED SOIL

PIPE MATERIAL

CS	CARBON STEEL
GALV	GALVANIZED STEEL
PVC	POLYVINYL CHLORIDE
SPVC	SCREENED POLYVINYL CHLORIDE

PIPE SERVICE

AIJ	AIR INJECTION
BIV	BIOVENTING
DR	DRAIN



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Checked	2/9/96			
Reviewed	2/9/96			
Approved	2/7/96			
Reg No		A	1/31/96	85% DESIGN
Date		Rev	Date	Description	By

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FULL-SCALE BIOVENTING SYSTEM
SITE FSA-1
AIR FORCE PLANT 4, TEXAS

LEGEND AND STANDARD TRENCH DETAILS

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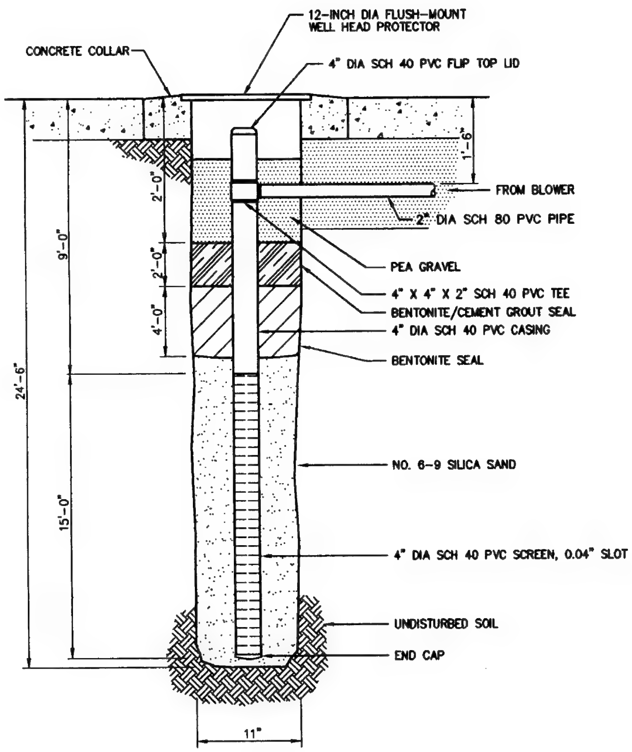

1 VENT WELL (VW) DETAIL

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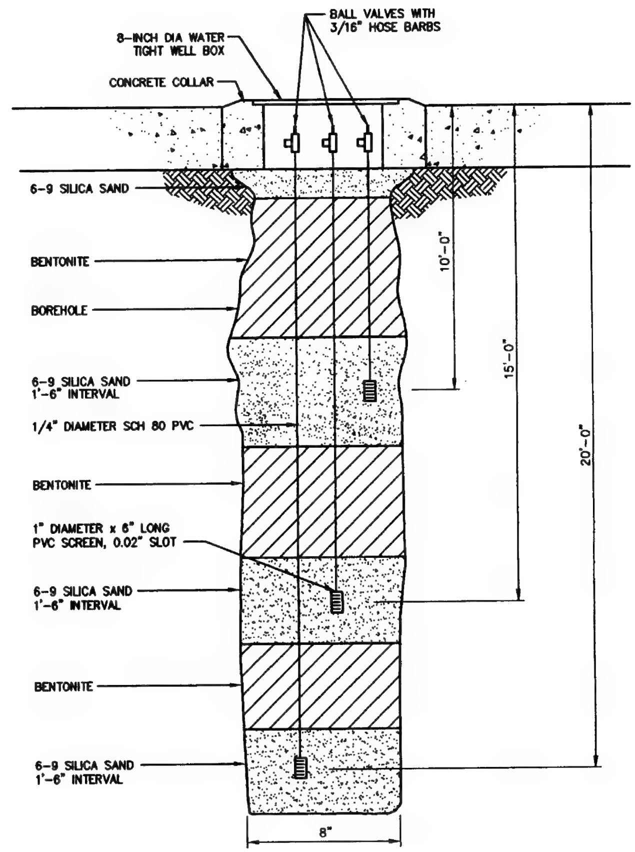

2 MONITORING POINT (MP) DETAIL

SCALE: NTS

Job No. 726876.17142			
Designed RAF			
Drawn MW			
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Reviewed	2/9/96		
Approved	[illegible]		
Reg No	A	1/31/96	65% DESIGN
Date	Rev	Date	Description

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FULL-SCALE BIOVENTING SYSTEM
SITE FSA-1
AIR FORCE PLANT 4, TEXAS

VENT WELL AND MONITORING POINT STANDARD DETAILS

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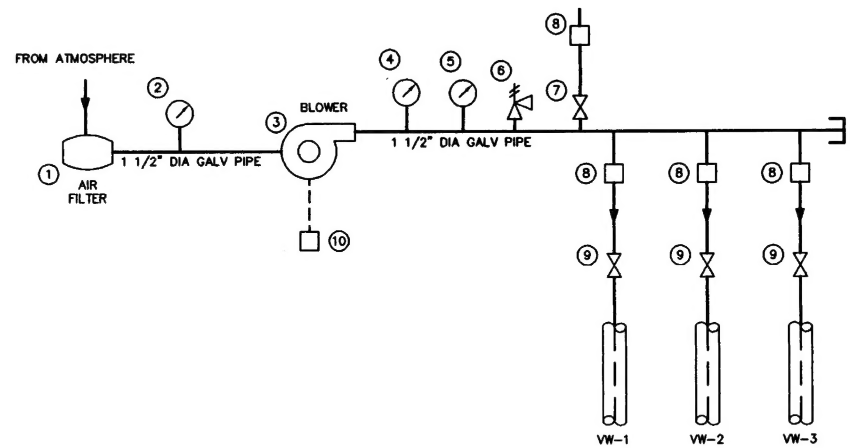

LEGEND

1. INLET AIR FILTER – SOLBERG F-30P-150, REPLACEMENT ELEMENT 30P
2. VACUUM GAUGE – WIKA® 611.10, 2 1/2" DIA., 0–30" H_2O, 1/4" NPT, LM (PART NO. 9852344)
3. BLOWER – GAST® 2.0HP R5125Q-50, 110 CFM AT 40" H_2O PRESSURE
4. TEMPERATURE GAUGE – ASHCROFT, 0–250°F, 1/2" NPT, CBM (Part No. 2A606 FROM GRAINGER)
5. PRESSURE GAUGE – WIKA 611.10, 2 1/2" DIA., 0–100" H_2O, 1/4" NPT, CBM (Part No. 9851879)
6. AUTOMATIC PRESSURE RELIEF VALVE – GAST AG258, SET TO RELEASE AT 100" H_2O PRESSURE
7. MANUAL PRESSURE RELIEF (BLEED) VALVE – 1 1/2" GATE
8. FLOW MEASURING PORT FITTED WITH PLUG (1/4"x 1/8" NPT BRASS REDUCING BUSHING, 1/8" NPT BRASS PLUG)
9. FLOW CONTROL VALVE – 1 1/2" GATE
10. STARTER

1 BLOWER PIPING AND INSTRUMENTATION DIAGRAM

SCALE: NTS

Job No. 726876.17142				
Designed RAF				
Drawn MW				
Checked RSB	2/9/96			
Reviewed	2/9/96			
Approved	2/1/96			
Reg No		A	1/31/96	65% DESIGN
Date		Rev	Date	Description	By

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Denver, Colorado (303) 831-8100

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)
FULL-SCALE BIOVENTING SYSTEM
SITE FSA-1
AIR FORCE PLANT 4, TEXAS

BLOWER P & ID

DRAWING NO G-0.4 REV A

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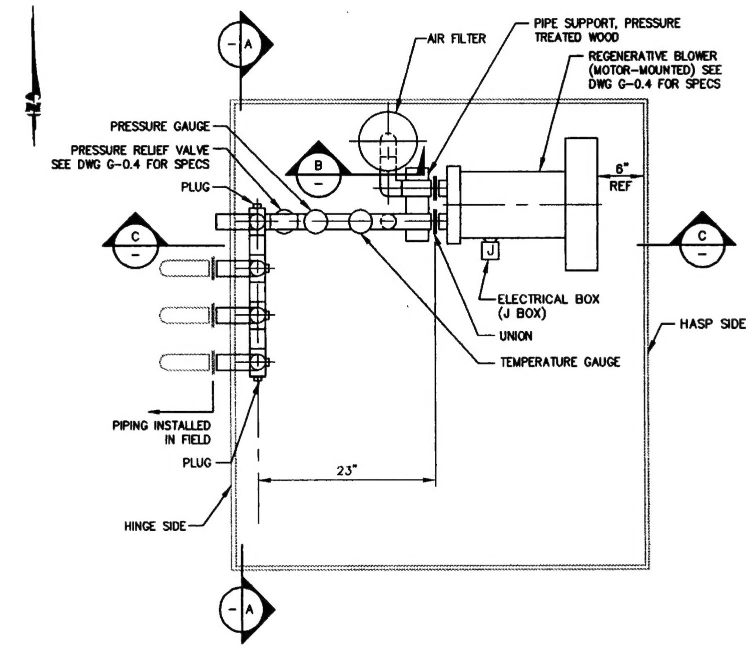
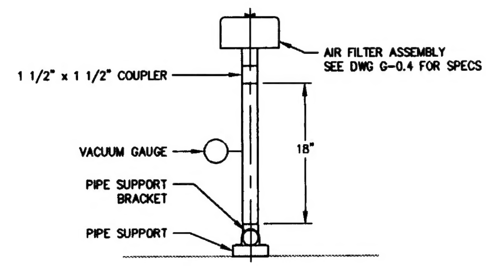
NOTES:

1. SHOP CORE HOLES TO PIPING DIMENSIONS
2. ALL PIPING 1 1/2" DIA. GALVANIZED STEEL, UNLESS OTHERWISE NOTED
3. SEE DRAWING G-0.6 FOR BLOWER BUILDING DETAILS



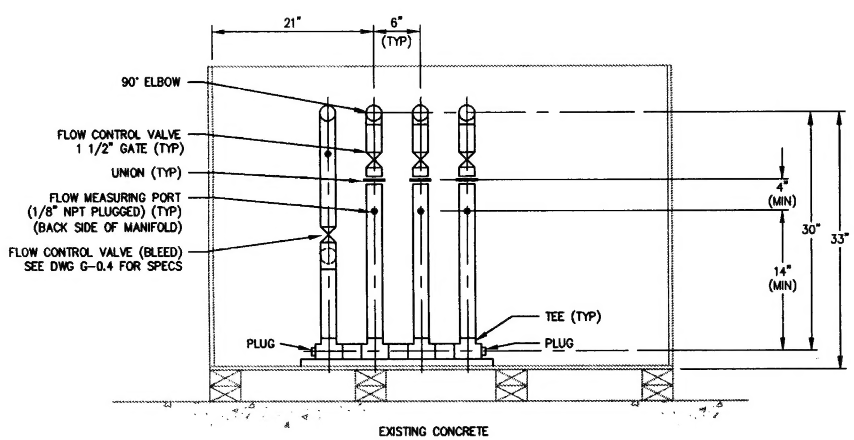
1 BLOWER PIPING LAYOUT PLAN DETAIL

3/4" = 1'-0"



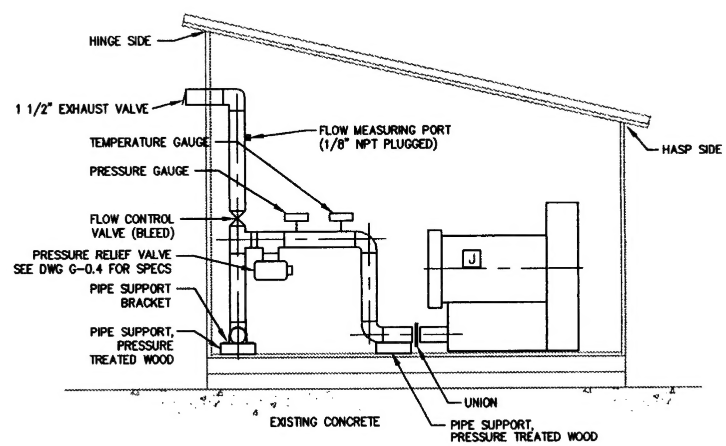
B BLOWER INLET PIPING SECTION

3/4" = 1'-0"



A MANIFOLD DETAIL SECTION

3/4" = 1'-0"



C BLOWER OUTLET PIPING SECTION

3/4" = 1'-0"

Job No. 726876.17142				
Designed RAF				
Drawn MW				
Checked	2/9/96			
Reviewed	2/9/96			
Approved	2/7/96			
Reg No	A	1/31/96	65% DESIGN	
Date	Rev	Date	Description	By

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AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)
FULL-SCALE BIOVENTING SYSTEM
SITE FSA-1
AIR FORCE PLANT 4, TEXAS

BLOWER PIPING LAYOUT DETAIL

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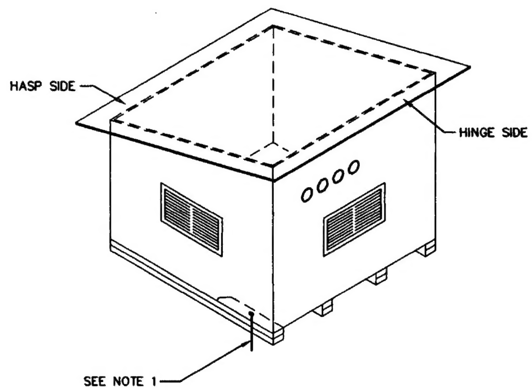
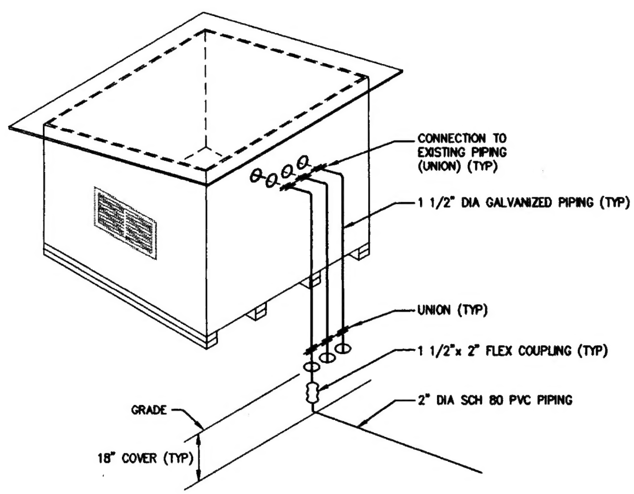


NOTES:

1. FIELD SECURE BLOWER SHED TO CONCRETE PAVEMENT AT 4 LOCATIONS BY THRU BOLTING. USE 3/8"x 6" LONG ST STL WEDGE ANCHOR BOLTS

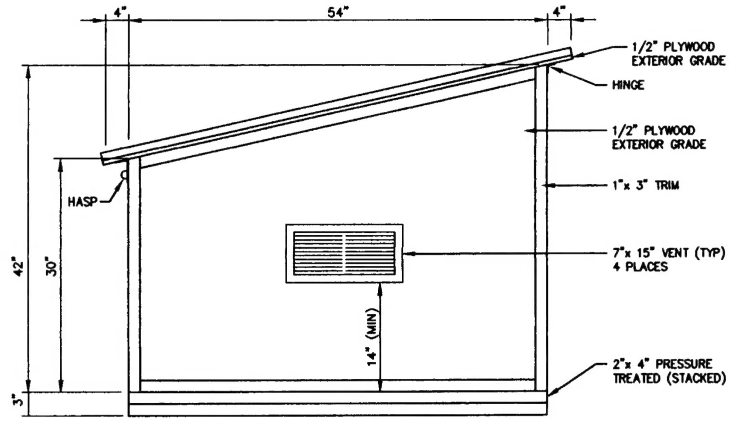
1/– BLOWER SHED FIELD INSTALLATION DETAIL

NOT TO SCALE

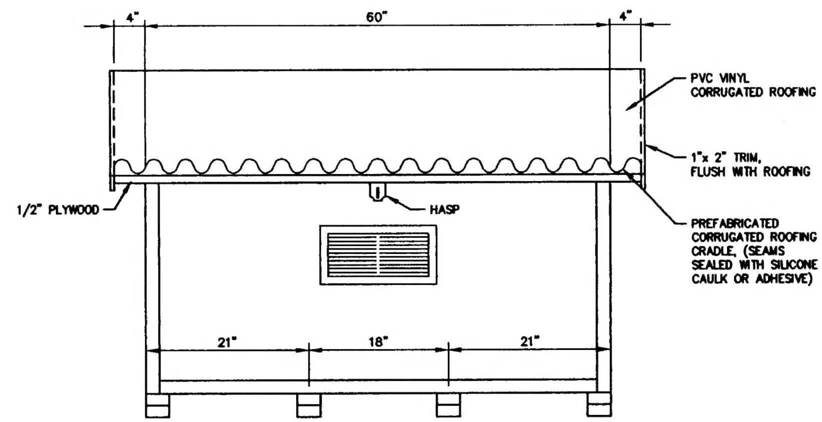


2/– TYPICAL MANIFOLD DISCHARGE PIPING LAYOUT

NOT TO SCALE



SIDE ELEVATION



FRONT ELEVATION

NOTES:

1. 2"x 2" FRAME CONSTRUCTION
2. FLOOR CONSTRUCTED OF 3/4" EXTERIOR GRADE PLYWOOD
3. ROOF CONSTRUCTED OF 1/2" EXTERIOR GRADE PLYWOOD COVERED WITH PVC VINYL CORRUGATED ROOFING

3/– BLOWER SHED CONSTRUCTION DETAIL

3/4" = 1'-0"

Job No.	726876.17142
Designed	RAF
Drawn	MW
Checked	2/1/96
Reviewed	2/6/96
Approved	2/7/96
Reg No	
Date	

Rev	Date	Description	By
A	1/31/96	85% DESIGN	

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FULL-SCALE BIOVENTING SYSTEM
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AIR FORCE PLANT 4, TEXAS

BLOWER SHED FIELD INSTALLATION DETAIL AND BLOWER SHED CONSTRUCTION DETAILS

DRAWING NO: G-0.6 REV: A

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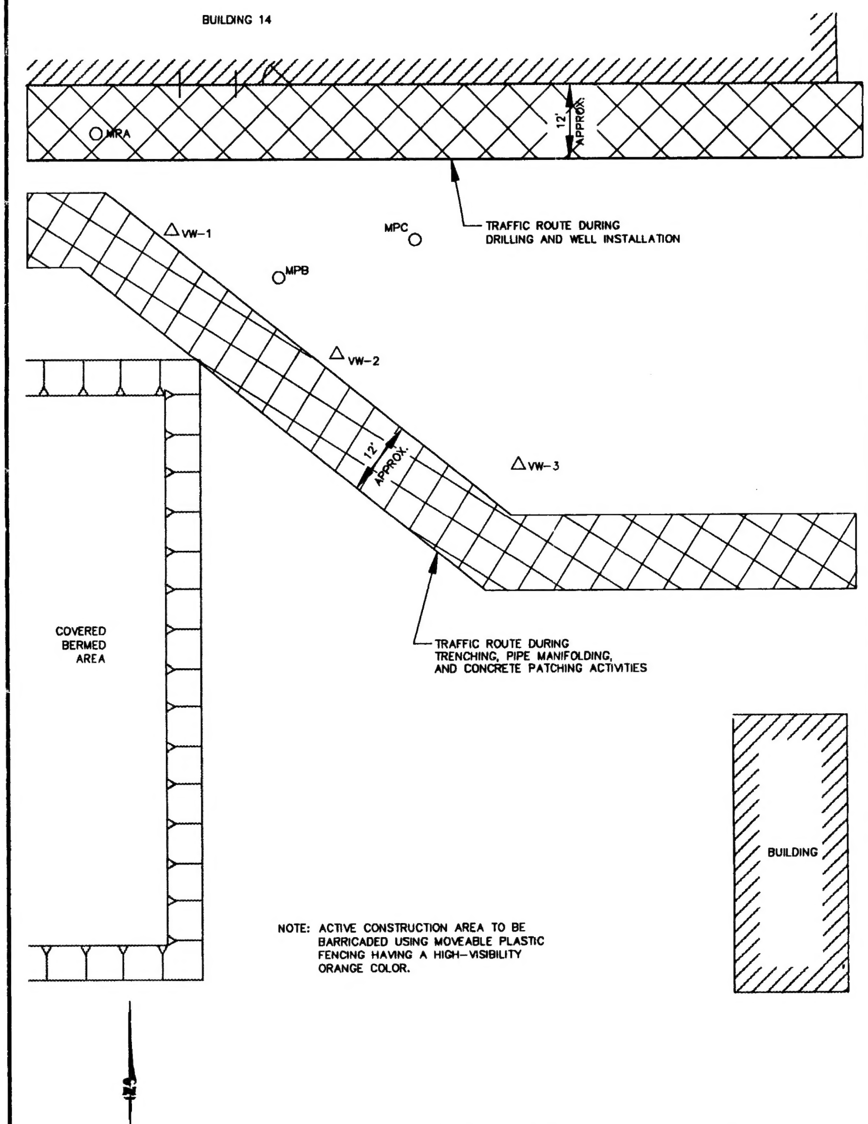

TRAFFIC ROUTES DURING SYSTEM INSTALLATION

SCALE: 1" = 20'

Job No. 726876.17142			
Designed RAF			
Drawn BTP			
Checked	2/9/96		
Reviewed	2/9/96		
Approved	2/12/96		
Reg No	A	1/31/96	65% DESIGN
Date	Rev	Date	Description

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AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE (AFCEE)
FULL-SCALE BIOVENTING SYSTEM
SITE FSA-1
AIR FORCE PLANT 4, TEXAS

TRAFFIC ROUTES DURING SYSTEM INSTALLATION

DRAWING NO G-0.7 REV A

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